

Da.Ma.Tra: Material Traceability Database



Iliaria Oberti and Ingrid Paoletti

Abstract The chapter summarises the content and objectives of the Da.Ma.Tra (Material Traceability Database) research project, funded by the Lombardy Region within the “Smart Living” competition call. The purpose of the project is to build a web-based digital platform prototype that can handle the constructive traceability of materials for civil buildings. The project’s attention to new materials has a specific focus on the use of bio-based materials and agricultural waste in construction. The economic value of this waste can be increased by encouraging reuse and recycling. This aspect places the research at the edge of the initiatives that favour the concept of sustainable architecture within the broader vision of a circular economy.

Keywords Traceability · Materials · Innovation · Reuse · Recycling

1 Introduction

The possibility of tracking products and artefacts is very common in areas that are far from architecture; for example, consider the food products (Engelseth 2013) or the raw materials of industrial components. Today, however, in virtue of a renewed interest, the development of dedicated standards and the greater public awareness make it increasingly important to also trace the materials in construction.

Thomas Rau states that it is time to imagine material rights, thus making sure not to neglect the effects of our economic activity on the planet and giving each material a sort of identity card to avoid it becoming anonymous as waste and losing track of it. To maintain this system, products must be consumed in ever-increasing amounts (Rau and Oberhuber 2019).

Major global issues are linked to our economic system organised in a linear way where we extract, use and design without thinking about raw material waste. For this

I. Oberti (✉) · I. Paoletti
Architecture, Built Environment and Construction Engineering—ABC Department, Politecnico di Milano, Milan, Italy
e-mail: iliana.oberti@polimi.it

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reason, knowledge and traceability of materials can become an information tool, but also one of control and awareness, which can move new economic levers.

The idea and the goal of the research project is, therefore, to develop a simple yet effective method to trace the materials present in a building to be able to know always their origin, and therefore the need for maintenance, replacement or disposal.

2 The Research Project

The Da.Ma.Tra (Material Traceability Database) project involves the construction of a web-based digital platform prototype that manages the constructive traceability of materials for buildings. In particular, the new service product, developed on the basis of Open Innovation, is directed towards the use of natural materials and agricultural waste as well as naturally based components.

The project's attention to new materials has a specific focus on the use of agricultural waste in construction. The economic value of this waste can be increased by encouraging reuse and recycling.

The project builds on a previous experience in public shipbuilding: Mo.Ma.Tra (Material Movement Traceability) which concerns a prototype software platform that manages the constructive traceability of a roadway infrastructure, developed with the logic of Open Innovation, and which has already been submitted to the first trial of an initial set of road works.

Since control instances, like safety and efficiency, are not fundamental for public construction and do not stop at the time of construction, there was a desire c model and the Mo.Ma.Tra. experimentation along the following lines:

- extension to private civil construction;
- extension to the operational time of the ordinary and extraordinary exercise of the buildings' life;
- extension to the use of unconventional materials in construction, particularly bio-based materials and straw.

Project objectives are therefore to

- prepare a new prototype in accordance with the above-mentioned extensions that specifically take account of construction methods and innovative type materials;
- carry out an experiment on a significant set of buildings;
- pre-market the new software solution in the form of a product-service.

This development takes place with the integration of ICT technologies, with the aim of increasing safety and the functional and operational efficiency of the buildings.

In particular, the development issue which was directly addressed is "Development of innovative technologies for the industrialisation of production processes in construction and for the integration of information between the various parties involved in the construction supply chain, through the development of innovative

digital solutions”, namely the Da.Ma.Tra. software module, which is inserted as a documentation and management element with BIM systems.

The level of the technology maturity of this project has risen from a TRL (Technology Readiness Levels) 4 value (Component and/or Breadboard Laboratory Validated) to the completion of level 7 on a scale of 9 (Heder 2017).

It is thus understandable that a system like Da.Ma.Tra. intends to respond in a timely manner to the need of providing BIM model systems dedicated to private civil construction design, and in particular to the precise traceability of each moment and material of the time of construction.

The opening at this stage to the use of innovative materials and technologies has important repercussions for the project. These relate to the ecological impact of the materials used in the building industry and, in particular, in the assembly phase within the building itself, as well as producing a significant documentary system of the use of these new materials and technologies useful to evaluate their functional-energy value from the moment they are installed.

Da.Ma.Tra. makes it possible to record building energy and the building’s static characteristics from the time of construction (or restructuring), in order to provide timely information on the building’s history in case of damage, disasters or earthquakes, as well as in subsequent modernisation, adaptation, renovation and restoration interventions.

Da.Ma.Tra. specifically addresses the documentation of new building construction, but it can also be applied to the documentation of interventions on buildings that are already built. Thus, it provides a significant contribution to the precise documentation concerning seismic adjustments, building renovations, and energy and/or structural upgrading.

Finally, since the software solution to be implemented has a configurable architecture such as SAAS, through a hypertext protocol secure interface, this project aims to also contribute to the intelligent management of information via the cloud, laying the basis for the implementation of intelligent analysis modules of aggregate information for all the buildings documented by Da.Ma.Tra. (Big data analysis).

However, this software solution’s real forte lies in the possibility of effectively supporting the infrastructure’s maintenance management once constructed. The detailed, documentation of the time and the point of origin of each material, equipment, system component, facilitates the planning of ordinary operations and promptly and efficiently intervenes in the event of a failure; this is currently not possible because the modelled property of infrastructure is not sufficiently documented, organised or available.

Given that this feature is able to respond to a need for the control and quality of any type of construction, the company is interested in extending the model to a new software platform version which would support the following improvements:

- the incorporation of the actions and materials of private buildings;
- a more stringent extension during building operations.

For the best implementation of these improvements, the project partnership consisted of companies and the university using the following criteria:

- the direct involvement of the company that developed the first software version (Mo.Ma.Tra);
- the acquisition of the latest innovations in the field of architecture and of new materials;
- the identification of a company in the construction sector has an innovative approach, capable of providing first-hand information on the construction dynamics of private buildings and for field testing the new platform.

This project stems from a liaison between companies, research centres and institutions promoted by Confartigianato Lombardia. In fact, this organisation is in this case responsible for scouting category project proposals, matching skills and the dialogue with the academic entity, in particular, the Politecnico di Milano. This project, therefore, assumes a paradigm value of a dynamic, which is to be encouraged, for the involvement of SMEs around the themes of innovation in a fruitful exchange with universities and research centres and in a perspective of a system spill-over on the entire artisan sector. Even before the specific impact on the construction sector supply chain, it is therefore intended to emphasise this project's "industry" scope in a sector such as construction, which has a low integration and innovation rate.

The following points can be highlighted as regards this research's direct impact:

- the meeting of the moment of construction and that of documentation in the act of building, in direct connection with upstream planning and downstream management;
- the availability of a BIM module for direct and immediate use;
- the preparation of a platform capable of connecting the different actors in the construction industry, around each individual construction, with the intrinsic increase in control and safety, and therefore, in the final analysis, the qualitative value of a building.

The platform becomes a synthesis and macro-assessment tool at the time in which it enables the intelligent aggregation of information of all the surveyed and documented buildings, with clear advantages in the field, in urban planning and in the area of statistics on materials and technologies.

3 Innovative Ecological Materials and the Circular Economy

In its broad spectrum, the research project aims to promote a specific focus on innovative materials and products to be used in the building sector, so that through the achievement of the traceability objective, it is possible to build an archive of constantly evolving materials.

In particular, the focus is on all those materials that include waste from the agricultural sector among their constituent raw materials. This pre-consumer waste may

From a linear to a circular economy

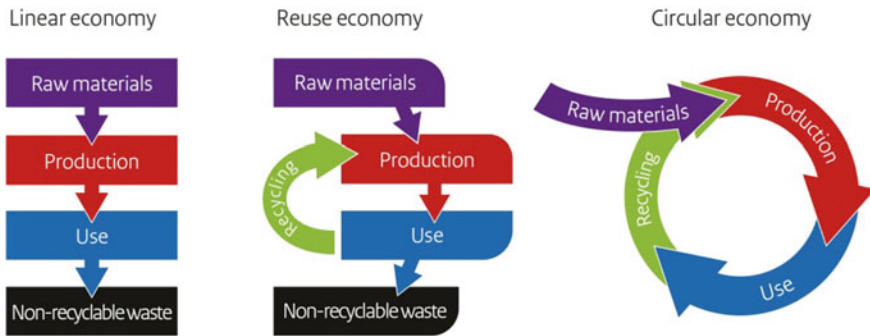


Fig. 1 Linear approach and circular economy approach. (Source www.government.nl/topics/circular-economy/from-a-linear-to-a-circular-economy)

constitute a valuable resource for the building industry, allowing it to produce and develop materials that are alternatives to those that are synthetic.

This aspect places the research project in the wake of the initiatives that favour the concept of sustainable architecture within the broader vision of the circular economy, as opposed to the linear economy (Fig. 1).

The first thoughts on the circular economy were produced by a Swiss architect, Walter R. Stahel, in 1976 and included in a report presented to the European Commission, entitled “The Potential for Substituting Manpower for Energy”. The salient aspect of this new economic approach is the ability for self-regeneration within an industrial system through the use of renewable energies, limiting the use of chemical substances that prevent or restrict the reuse of products and the elimination of waste (McDonough and Braungart 2013). Referring to the two main types of material flows, according to the circular economy concept, biological materials must be capable of being reintegrated into the biosphere, and technical materials must be destined for upgrading, limiting interference with the biosphere (Ellen McArthur Foundation 2013, 2015) (Fig. 2).

These considerations are to be included in the design of materials, products, components and systems, so that the importance of activating circular flows in the use of resources is assessed (European Environment Agency 2016).

According to Ellen MacArthur Foundation’s studies, now shared by the global scientific community, it is necessary to consider three basic principles in order to be able to guide actions in a circular economy perspective.

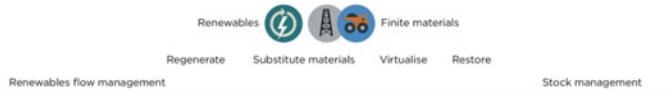
The first refers to “the preservation and the increase of natural capital”, with the goal of keeping the availability of non-renewable resources under control and to balance the flows of renewable resources, replacing fossil fuels with renewable energy sources, or by working in such a way that the raw materials, at the end of the product life cycle, are not lost but reintegrated into the ecosystem. This means

OUTLINE OF A CIRCULAR ECONOMY

PRINCIPLE 1

1

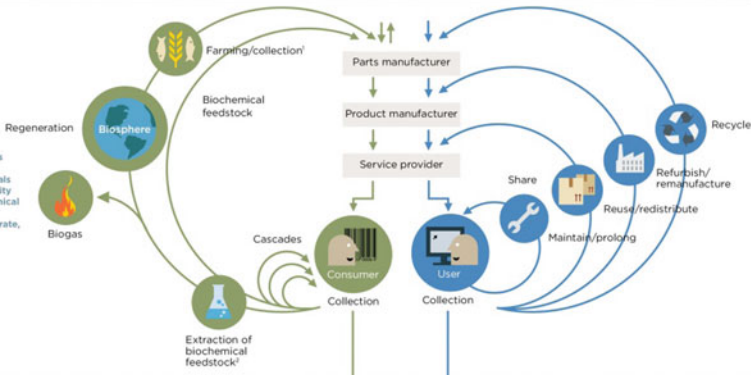
Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows
ReSOLVE levers: regenerate, virtualise, exchange



PRINCIPLE 2

2

Optimize resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles
ReSOLVE levers: regenerate, share, optimise, loop



PRINCIPLE 3

3

Foster system effectiveness by revealing and designing out negative externalities
All ReSOLVE levers



Fig. 2 Diagram of flows within the circular economy. (Source www.ellenmacarthurfoundation.org/circular-economy/infographic)

that products should be designed, and then manufactured, to make disassembly and reuse operations easier.

The second principle is linked to the “optimisation of resource efficiency” through the circulation of products that reach the highest level of utility in all the stages of the life cycle, both within the technological cycle and the biological cycle.

Finally, the last principle is that of “enhancing the system’s effectiveness” through the identification and elimination of negative aspects related to the use of resources, such as the production of harmful substances, the pollution of the air, water and soil, and the greenhouse effect.

Certainly, the passage from the linear economic approach, practiced until recently, to the circular approach, which has emerged today, involves great efforts from everybody (Prieto-Sandoval et al. 2018) and requires the need to operate in two directions. One should be focussed on the systemic enhancement of the organisation between the different phases of the construction process and between the operators involved therein. The other, however, should push to encourage cooperation between different productive sectors external to the building sector.

This second direction opens up to the theme of pre-consumer waste management which can only find valid responses through the creation of horizontal supply chains

that will allow a production sector to use as raw material that another it considers to be waste (Talamo and Migliore 2017).

Considered the continuous depletion of resources and the consequent environmental degradation caused by the increasing demand and use of virgin raw materials (UNEP 2019), the promotion of the recovery strategy and the utilisation of pre-consumer waste must be carefully evaluated. This manner of considering waste implies a revision of production processes to enable the emergence of a system logic over the linear system. In this new vision, the manufacturing process of an object, whatever it may be, is no longer analysed as a set of sequential actions, but is examined in its entirety and related to other interconnected systems.

In this logic, the waste, transitioning from this condition to a secondary raw material, can be introduced into the supply chain where it originated or into parallel supply chains, by “jumping the chain”.

And this is the circumstance that the Da.Ma.Tra. project hopes to bring to light, in particular by tracking materials and building products that include, amongst others, raw materials from pre-consumer agricultural waste. The agri-food sector is potentially capable of providing material in circular economy processes that can be developed particularly for the construction sector.

Studies, already started some time ago, are specifically directed towards the use of waste from the cultivation of cereals, and particularly, rice, with an estimated global production of 501.4 million tonnes for 2018/2019 (USDA 2019).

The by-products and waste from rice processing are the husk, bran and rice straw, in particular. As regards the husk and bran, there is widespread use oriented towards the production of energy from biomass or intended for the food and farming sector. For rice straw, however, the management takes place within the same process as rice cultivation and disposal takes place through two techniques: the burning of the straw in the field and burying it in the land in order to restore to the soil some of the nutrients that were taken during the plant's growth.

The attempt to promote this waste for the production of building materials and products has been taking place since the first decades of the twentieth century, having studied the possibility of compressing the rice straw at high temperatures to obtain panels with variable density (Wei et al. 2015).

Currently, the main experiments concern the production sector for thermal insulation materials, the advantages of which can be analysed under different points of view: the consumption of other raw materials avoided for the production of alternative thermal insulation; the decrease in the consumption of primary energy required for heating buildings; the reduction of carbon dioxide into the atmosphere; the elimination of the negative effects linked to freely burning rice straw. Although the creation of materials to be destined for the production of thermal insulation seems to be the most pursued, developments can be highlighted for other innovative materials, in their composition, and with a reduced environmental impact, such as lightweight screed, mortar, and plaster with high thermal performance.

With the Da.Ma.Tra. the project, the main objective is the traceability of materials presents inside a building in order to know their origin, the need for maintenance, replacement or disposal with a view to more effective management of the same

building. With the project, it is hoped that a rich archive can be created that will gather building materials and products with high innovation characteristics and reduced environmental impact, so as to respond to the principles of the circular economy.

4 Conclusions

The role of the collaboration between Politecnico di Milano and the mentioned companies has generated a transfer of information that can increase an innovative workflow.

The Politecnico di Milano has accompanied partner companies in this direction to identify the characteristic parameters of traditional materials (constant information to be identified in specific harmonised standards at European level) and in the analysis of the opportunity of finding/identifying characteristic data of those architectural and technical elements that are emerging in the panorama of modern construction and for which there are no uniform regulatory views.

Specifically encoded are the parameters of the main innovative and non-conventional insulations, as well as the finishing surfaces for bioconstruction and for sustainable architecture, which is predominantly dry assembled.

In order to allow the project tool to be able to cover a wider spectrum of interventions (including experimental ones), there has been a close integration between research and industry partners which facilitated the identification of elements for possible dynamism in the planning and implementation phases of the architectural/engineering projects that are typical in civil construction.

The systematisation of transmitted data, with those acquired by the companies, has allowed for appropriate software libraries to be created which, from the perspective of the Building Information Model and placed alongside the tracking processes, facilitate the verification of the output quantitative and qualitative parameters of the construction process. All this is to allow the testing and implementation of performance in terms of control, safety and energy efficiency at the different periods of the building's life.

In fact, and in conclusion, shared expertise was created on the tool capable of anticipating a product-service that will support the specific software on the documented use of new materials and new construction technologies.

This project's output-product was, therefore, a product-service, targeting construction companies, capable of interfacing with BIM systems on the one hand, and with real estate economic-financial management systems on the other, which is nowadays increasingly crucial.

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